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LOW TEMPERATURE MECHANICAL PROPERTIES OF 8Al-1Mo-1V TITANIUM ALLOYS AND COMPOSITE WELDMENTS

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ABSTRACT

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The mechanical properties of annealed 8Al-1Mo-1V titanium alloy sheet, 0.063-inch thick, were determined at temperatures from ambient to -253°C (-423°F). The alloy had high strength through the entire test temperature range. The tensile strength at -253°C (-423°F) was approximately 75 percent greater than the ambient temperature tensile strength. The elongation decreased from approximately 16 percent at ambient temperature to approximately 8 percent at -196°C (-320°F) and to less than 3 percent at -253°C (-423°F).

Weldments of 8Al-1Mo-1V titanium to 6Al-4V titanium were made by utilizing the TIG process with 6Al-4V titanium alloy filler. Similar weldments were made with the electron beam process without filler wire. Based upon typical strength values of 6Al-4V titanium alloy, the as-welded joint efficiencies of both types of weldments exceeded 95 percent over the entire range of test temperatures from ambient to -253°C (-423°F). The TIG weldments resulted in slightly higher strengths over the test temperature range except at room temperature, where strengths were approximately equal.

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LOW TEMPERATURE MECHANICAL PROPERTIES OF 8Al-1Mo-1V TITANIUM ALLOYS AND COMPOSITE WELDMENTS

SUMMARY

The mechanical properties of titanium alloy 8Al-1Mo-1V sheet, 0.063-inch thick, were determined at temperatures from ambient to -253°C (-423°F). The ultimate tensile strength increased from 158.1 ksi at ambient temperature to 279.1 ksi at -253°C (-423°F). The notched to unnotched tensile strength ratio dropped from 0.90 at ambient temperature to 0.81 at -129°C (-200°F) and decreased sharply to 0.51 at -253°C (-423°F). Composite weldments of titanium alloy 8Al-1Mo-1V to titanium alloy 6Al-4V were made by using both the TIG and electron beam welding processes. The TIG weldments were made with 6Al-4V filler wire; no filler wire was used with the electron beam welding process. Joint efficiencies produced by the TIG process were greater than those produced by the electron beam process. In both cases, however, the joint efficiencies were above 95 percent from ambient temperature to -253°C (-423°F).

INTRODUCTION

Titanium alloy 8Al-1Mo-1V, having an alpha rich-lean beta structure, has good forgeability and heat treatment qualities and also high strength and resistance to creep at ambient and high temperatures. This alloy was developed originally for jet engine compressor parts, i.e., discs, spacers, and blades, where high tensile properties and resistance to creep were of the utmost importance (Ref. 1).

This investigation was prompted by the need for additional low temperature data to fully evaluate the performance of this alloy over a wide variety of environments for potential use in advanced space vehicle ducting, structural members, and tank skins. The study was limited to the low temperature properties of the alloy in sheets of 0.063 inch in thickness, furnished by the Titanium Metals Corporation of America from Heat No. (210) D-3457. In addition, since the properties of this alloy are reportedly comparable to the 6Al-4V titanium at room temperature and superior at elevated temperatures, weldments of 8Al-1Mo-1V to 6Al-4V were prepared for evaluation at low temperatures. TIG (tungsten arc inert gas) weldments utilizing 6Al-4V titanium alloy filler and electron beam weldments without a filler were evaluated. Preparation of the sheet material before welding and the welding schedules used are described in the Appendix.

EQUIPMENT AND SPECIMEN CONFIGURATION

The descriptions of the testing equipment and specimen configuration are reported in reference 2.

RESULTS AND DISCUSSION

The compositions of the two titanium alloys investigated are shown in Table I. The 0.063-inch thick commercial grade sheet was tested in the as-received, single annealed condition.

The mechanical properties of the 8Al-1Mo-1V alloy listed in Table II show the ambient temperature tensile and yield strengths in the longitudinal direction to be 158.1 ksi and 150.0 ksi, respectively, and 279.1 ksi and 258.9 ksi, respectively, at -253°C (-423°F), which is an increase of approximately 75 percent. A comparison of the properties in both the longitudinal and transverse directions is shown in FIG 1. The percent elongation drops gradually from 14 percent at ambient temperature to 8.3 percent at -196°C (-320°F) and decreases sharply to 2.7 percent at -253°C (-423°F) in the longitudinal direction. The notched to unnotched tensile ratios indicate a decrease in toughness with a decrease in temperature (FIG 2). Notch sensitivity in the longitudinal direction is not quite as severe as that in the transverse direction. However, the notch sensitivity in the two directions exhibits a sharp increase at temperatures below -129°C (-200°F).

The 8Al-1Mo-1V sheet, 0.063-inch thick, was TIG welded to 6Al-4V sheet of the same thickness using 6Al-4V filler material. The low temperature tensile strengths of the composite weldments are shown in Table III. The TIG welds, transverse to the loading direction, increased in tensile strength from 137.8 ksi at ambient temperature to 257.6 ksi at -253°C (-423°F). (See FIG 3.) The average increase in strength was 29 ksi per 100°F decrease in temperature with joint efficiencies in excess of 95 percent for the test temperature spectrum. The electron beam weldments increased in tensile strength from 138.7 ksi at ambient temperature to 256.9 ksi at -253°C (-423°F). Joint efficiencies of the electron beam weldments were 95 percent or above for all test temperatures. Only three specimens of the total number of weldments tested failed in the fusion zone; the remainder failed in the 6Al-4V alloy base material. Low temperature tensile strengths of the 8Al-1Mo-1V TIG weldments with no filler added are shown in FIG 4 (Ref. 3). The strength values of composite weldments are lower than those from TIG weldments of 8Al-1Mo-1V, as would be expected considering the lower strength of the 6Al-4V alloy.

Macrostructures and microstructures of both types of weldments are shown in FIG 5 and 6. The heat affected zones common to the TIG weldments are shown at 100X magnification in FIG 5. The two upper microstructures in FIG 6 show the alpha rich-lean beta 8Al-1Mo-1V titanium and the alpha beta 6Al-4V titanium alloy sheet materials. The lower microstructure of the electron beam weld joint shows the same type of transition from the heat affected zone to the fusion zone as illustrated in FIG 5; however, transition from the base metal through the heat affected zones to the fusion zone occurs in a much narrower area. Preparation of the macrostructure and microstructures shown in FIG 5 and 6 is described in reference 4.

CONCLUSIONS

It was determined that titanium alloy 8Al-1Mo-1V has good mechanical properties in the temperature range of 27°C (80°F) through -129°C (-200°F). The composite TIG weldments utilizing 6Al-4V filler metal and the electron beam weldments resulted in weld efficiencies greater than 95 percent over the test temperature range from ambient to -253°C (-423°F). As determined from the evaluation of the one heat of 8Al-1Mo-1V titanium alloy, this alloy is not recommended for dynamic load applications at liquid nitrogen and liquid hydrogen temperatures because of the low ductility and increased notched sensitivity as measured by percent elongation and notched to unnotched tensile ratio, respectively.

APPENDIX

PREPARATION OF TITANIUM ALLOYS 8Al-1Mo-1V AND 6Al-4V SHEET PRIOR TO WELDING

Degrease by wiping with solvent (alcohol)

Soak in alkaline cleaner for 5 minutes (180°F)

Immerse in a water solution of 5 percent HNO_3 and 0.5 percent HF for 20 minutes

Rinse and dry by wiping with lint-free cloth or tissue

WELDING SCHEDULE FOR TIG WELDMENTS

Backing plate - Stainless steel
Filler - 1/16-inch diameter 6Al-4V titanium alloy
Electrode - 3/32-inch diameter thoriated tungsten
No. 8 metal cup
Copper hold down bars
Volts - 8
Amps - 170
Filler wire speed - 30 inches/minute
Carriage speed - 18 inches/minute
Argon cover flow rate - 30 cfh
Helium flow rate on trailing shield - 6 cfh
Helium flow rate on backing plate - 50 cfh

WELDING SCHEDULE FOR ELECTRON BEAM WELDMENTS

Machine - Hamilton Zeiss W1-2 Electron Beam Welder

Welding Pass

Beam diameter - 0.005 inch to 0.008 inch
Kilovolts - 110
Milliamps - 3.25
Travel speed - 30 inches/minute
Beam deflection (transverse to weld seam) - 0.020 inch, each side

Wash Pass

Beam diameter (defocused) - 0.040 inch to 0.050 inch
Travel speed - 30 inches/minute

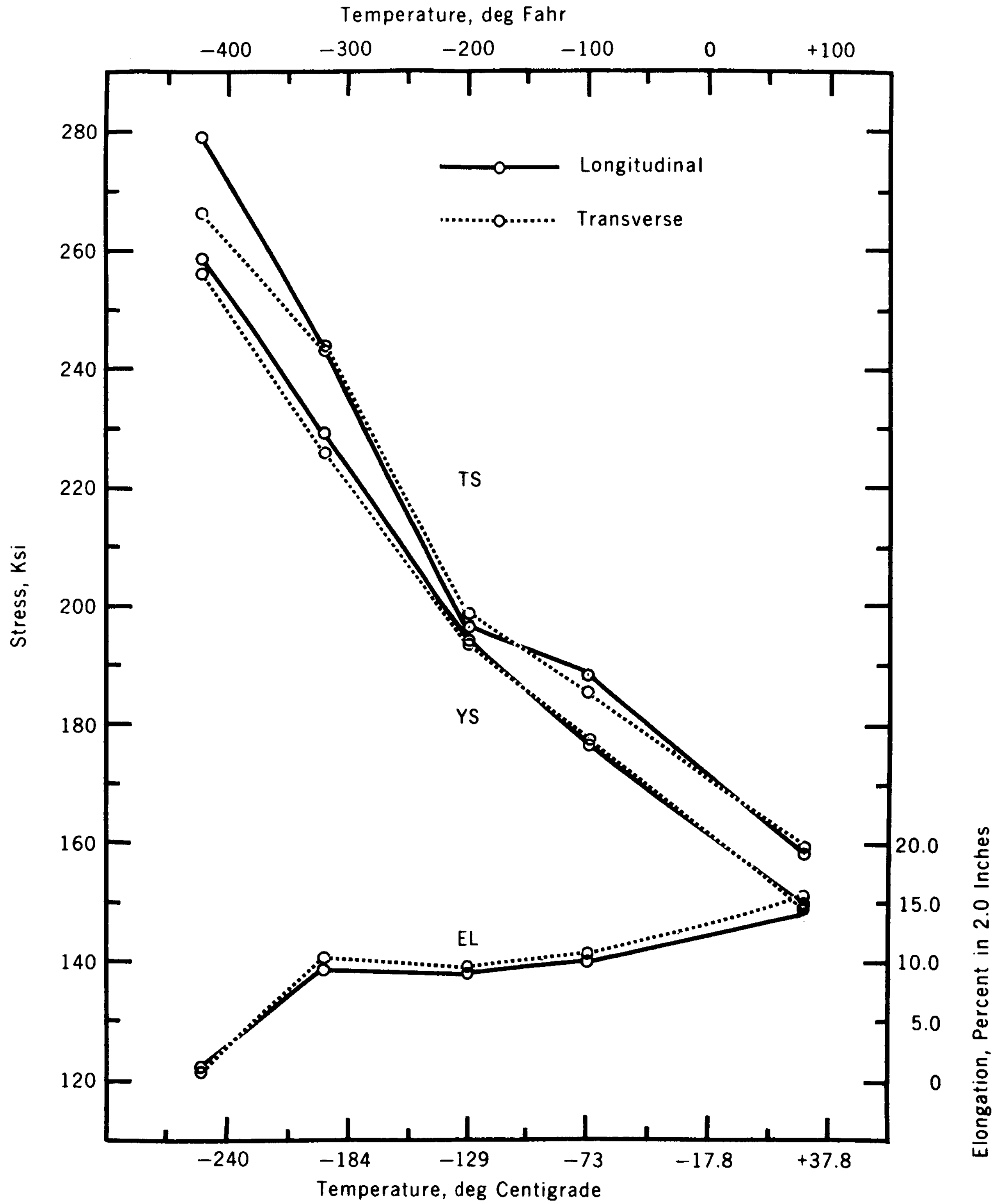

FIGURE 1 LOW TEMPERATURE MECHANICAL PROPERTIES OF 8AL-1MO-1V TITANIUM ALLOY SHEET (0.063-INCH THICK)

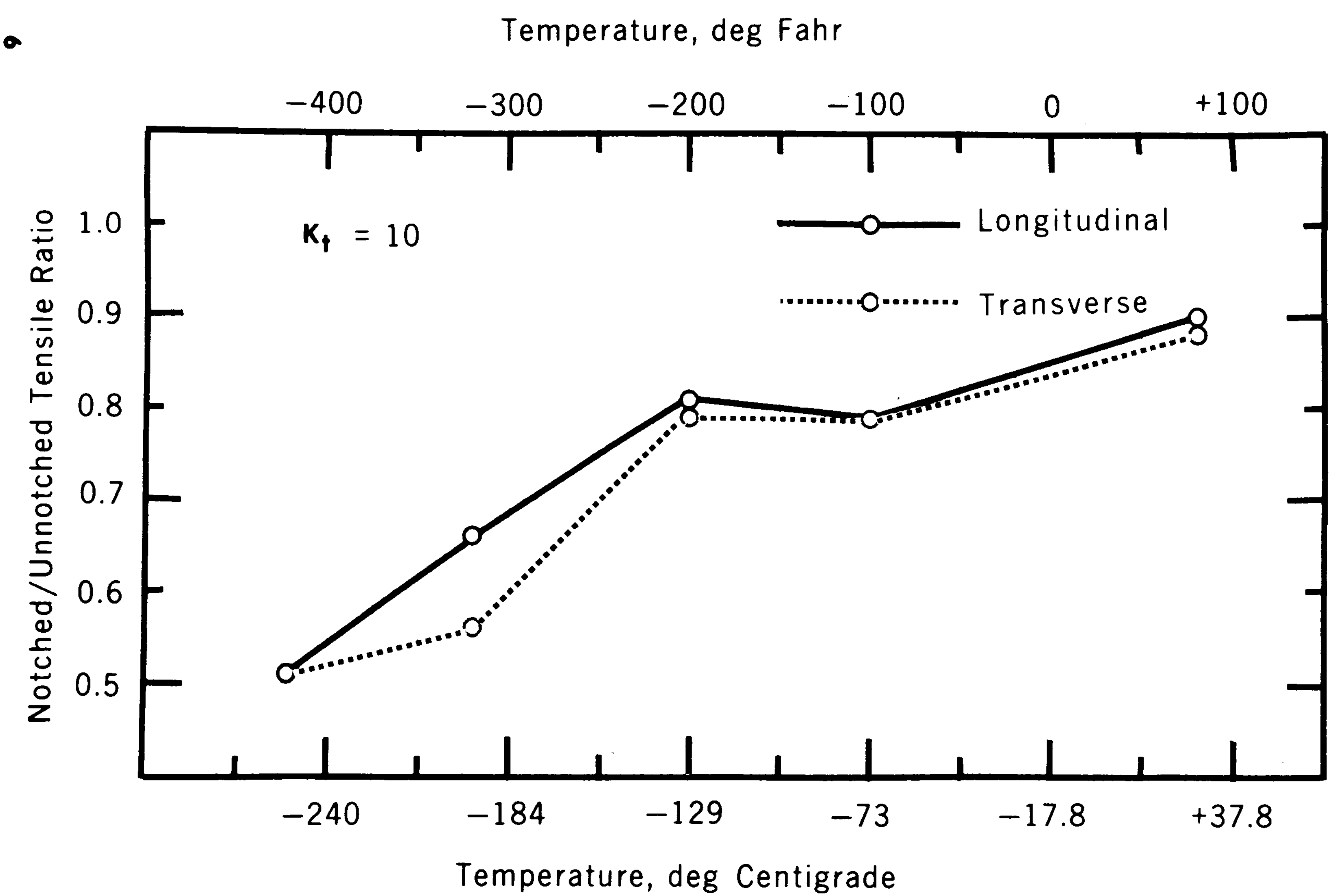

FIGURE 2 LOW TEMPERATURE NOTCHED/UNNOTCHED TENSILE STRENGTH RATIO OF 8AL-1MO-1V TITANIUM ALLOY SHEET (0.063-INCH THICK)

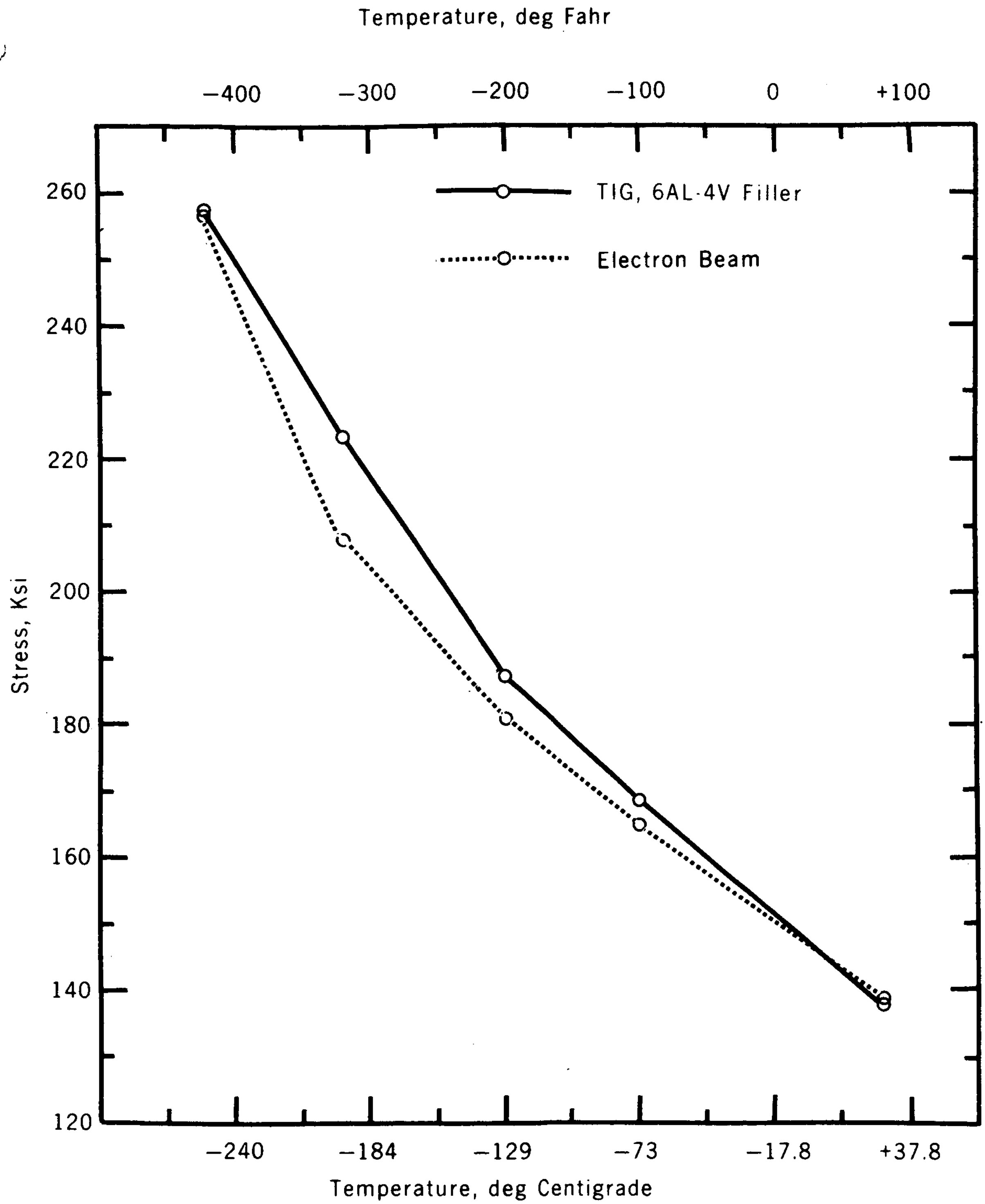

FIGURE 3 LOW TEMPERATURE TENSILE STRENGTHS OF 8AL-1MO-1V TITANIUM ALLOY SHEET WELDED TO 6AL-4V TITANIUM ALLOY SHEET (0.063 INCH THICK)

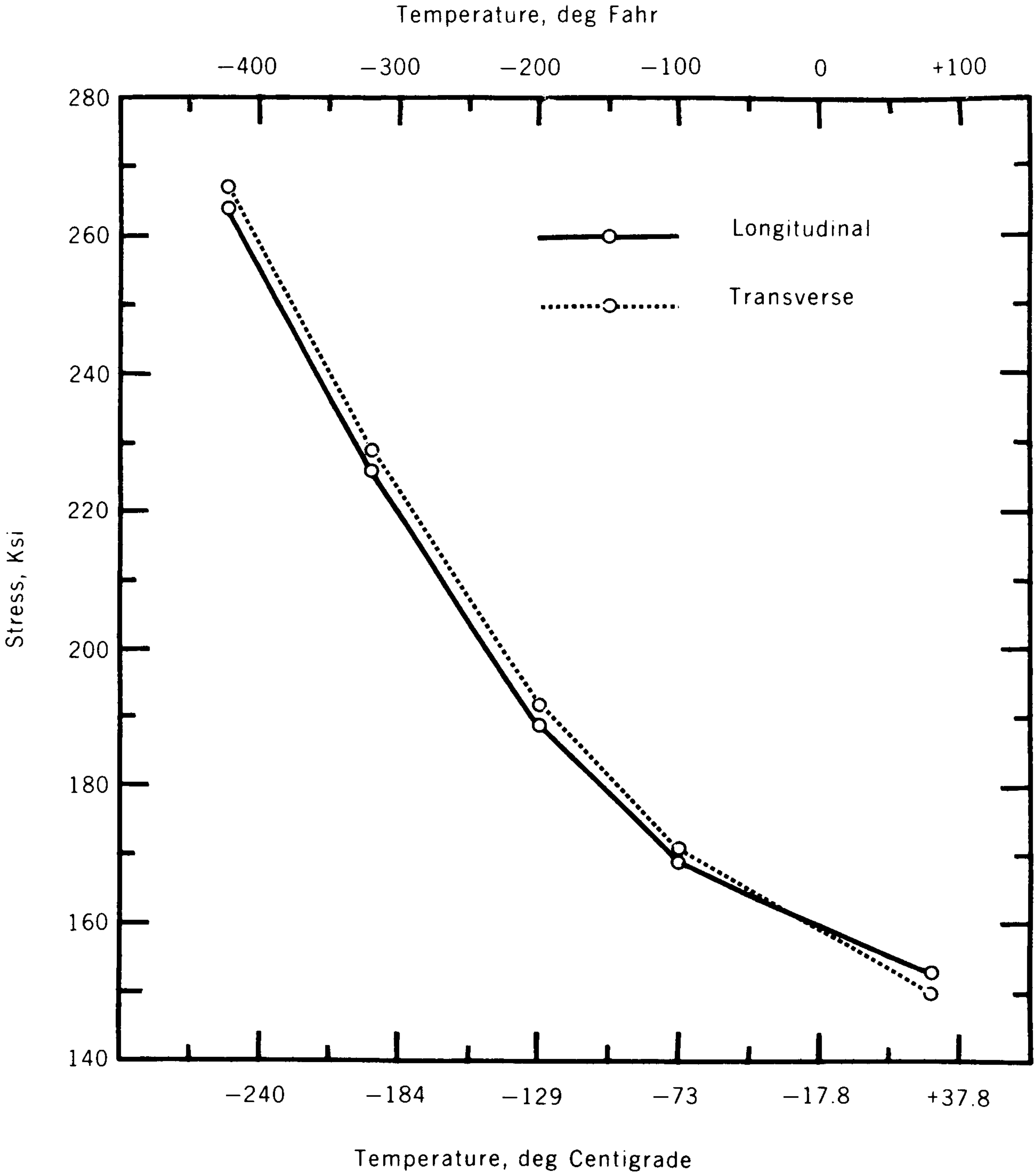

Figure 4 LOW TEMPERATURE TENSILE STRENGTH OF TITANIUM ALLOY 8AL-1MO-1V TIG WELDMENTS, NO FILLER

Extracted From Reference 3

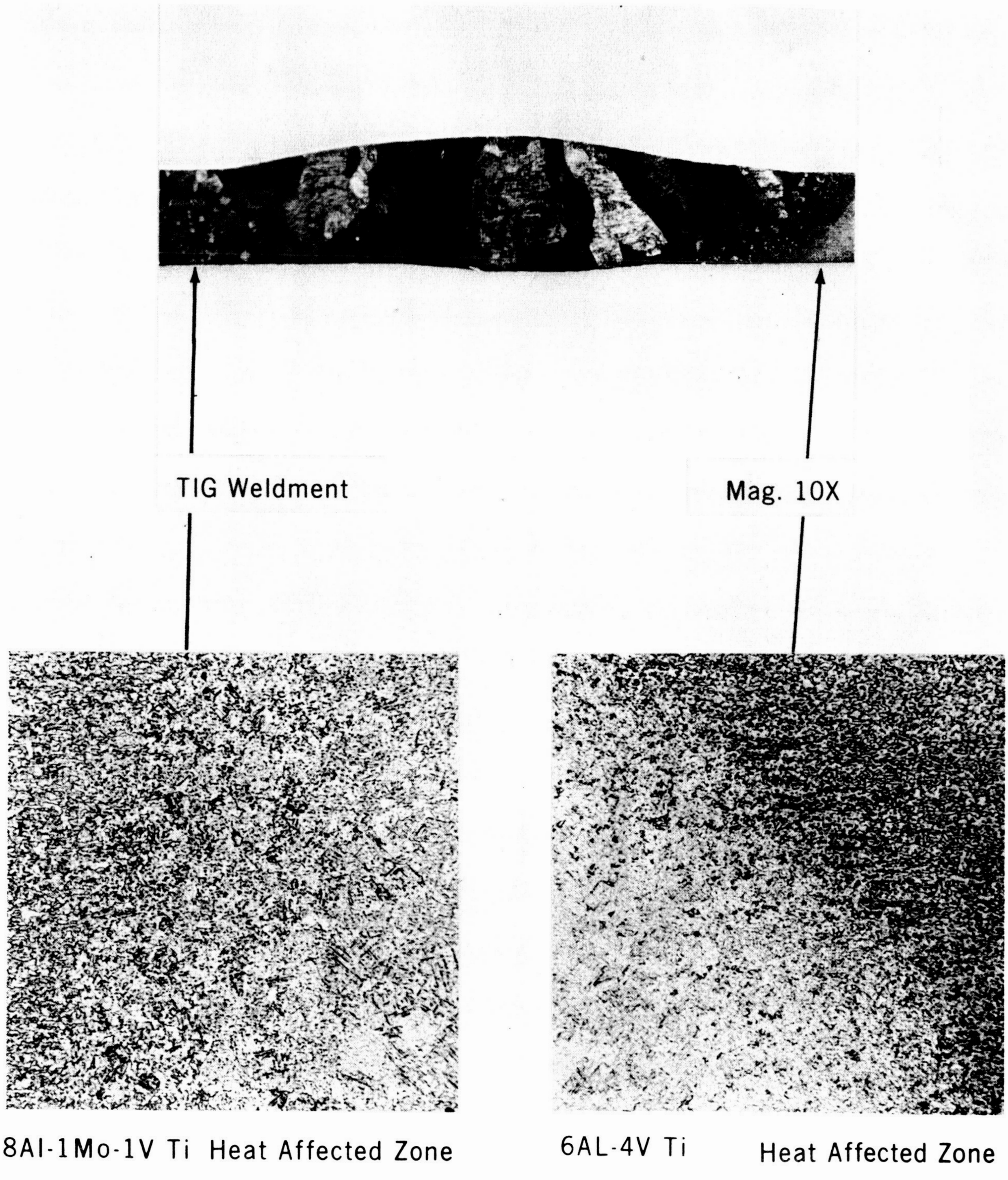

FIGURE 5 STRUCTURE OF TIG WELDMENT

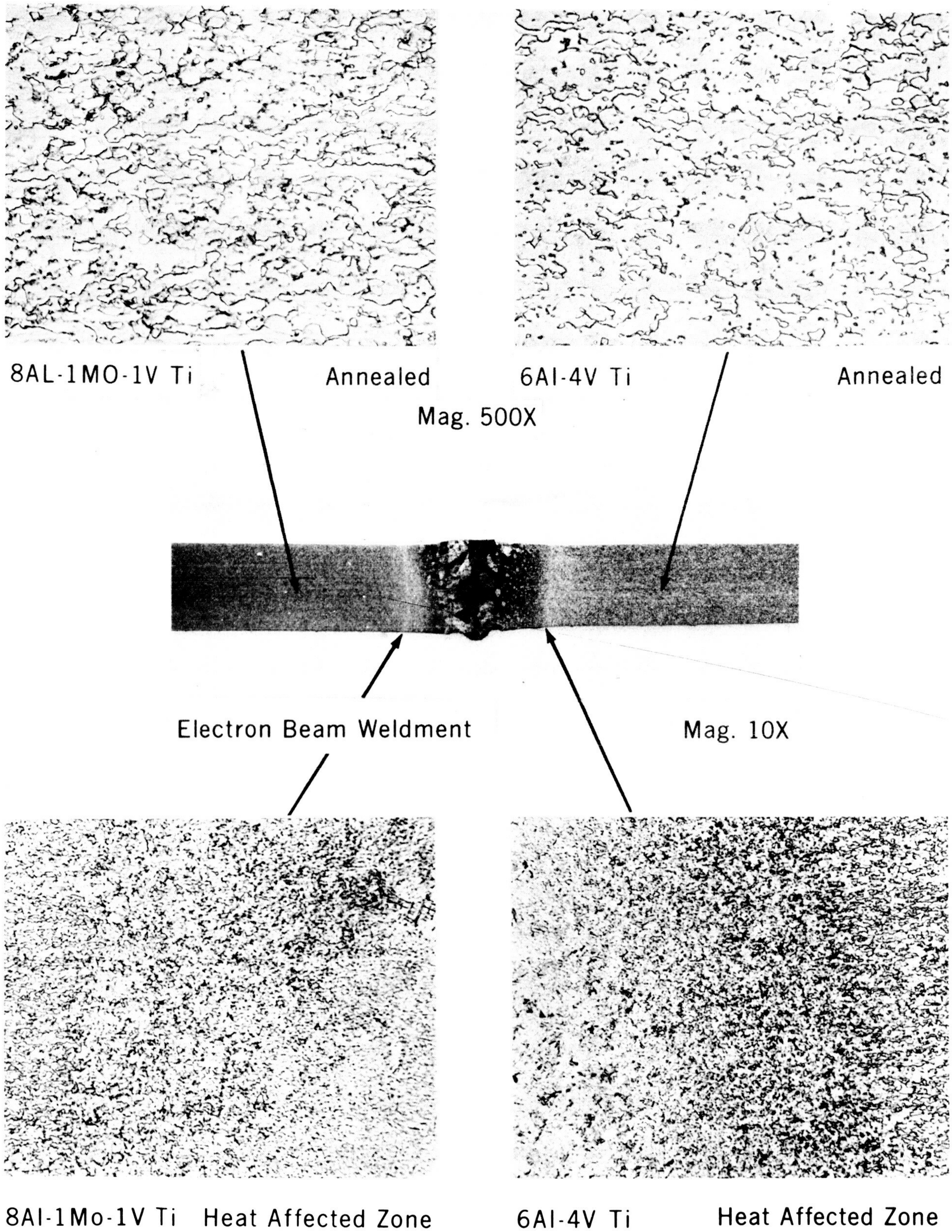

FIGURE 6 STRUCTURE OF ELECTRON BEAM WELDMENT

TABLE I

COMPOSITION OF TITANIUM ALLOYS 8Al-1Mo-1V AND 6Al-4V

Ti Alloy	C	Fe	Al	V	Mo	H_2	O_2	N_2
8-1-1[1]	0.025	0.08	7.9	1.0	1.0	0.004	0.090[2]	0.010
6-4[1]	0.020	0.13	6.1	4.0	-	0.006	0.087[2]	0.019

Note 1 - Vendor's Analysis
Note 2 - MSFC Analysis

TABLE II

LOW TEMPERATURE MECHANICAL PROPERTIES OF 8Al-1Mo-1V TITANIUM ALLOY

Temperature °C	Direction	Ultimate T.S. ksi	Y.S. 0.2% Offset ksi	El. 2-Inch Gage %	Notched Tensile Strength ksi (K_t=10)	Notched/ Unnotched Tensile Ratio
+27	Longitudinal	158.1	150.0	14.0	141.6	0.90
	Transverse	159.2	149.7	16.2	140.4	0.88
-73	Longitudinal	188.4	176.8	10.0	141.0	0.79
	Transverse	185.6	177.1	10.5	146.4	0.79
-129	Longitudinal	196.4	194.4	8.0	160.4	0.81
	Transverse	199.0	193.8	9.2	156.7	0.79
-196	Longitudinal	243.1	229.3	8.3	159.9	0.66
	Transverse	243.6	226.2	10.3	137.3	0.56
-253	Longitudinal	279.1	258.9	2.7	142.4	0.51
	Transverse	266.4	256.8	1.7	136.4	0.51

Note - Each strength value is an average of three or more specimens.

TABLE III

LOW TEMPERATURE TENSILE STRENGTH OF 8Al-1Mo-1V TITANIUM TO 6Al-4V TITANIUM WELDED JOINTS

Temperature °C	TIG Weldments* Ultimate T.S. ksi	Electron Beam Ultimate T.S. ksi
+27	137.8	138.7
-73	168.4	164.8
-129	187.1	181.0
-196	223.4	207.6
-253	257.6	256.9

* 6Al-4V Titanium Filler

Note - Each strength value is an average of three or more specimens.

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1. Titanium Metals Corporation of America, Properties of Ti-8Al-1Mo-1V.

2. Miller, P. C., "Low Temperature Mechanical Properties of Several Aluminum Alloys and Their Weldments," MTP-S&M-M-64-16, October 1961.

3. Schwartzberg, F. R., Osgood, S. H., and Keys, R.D., Cryogenic Material Data Handbook, F.4.6-3, Prepared under Contract No. AF33 (657-916) by the Martin Company, Denver, Colorado.

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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